RESEARCH, DEVELOPMENT & TECHNOLOGY TRANSFER
QUARTERLY PROGRESS REPORT

Wisconsin Department of Transportation
DT1241 02/2011

INSTRUCTIONS:
Research project investigators and/or project managers should complete a quarterly progress report (QPR) for each calendar quarter during which the projects are active.

WisDOT research program category: ☐ Policy research ☒ Wisconsin Highway Research Program ☐ Other ☐ Pooled fund TPF#		Report period year: 2014 ☒ Quarter 1 (Jan 1 – Mar 31) ☐ Quarter 2 (Apr 1 – Jun 30) ☐ Quarter 3 (Jul 1 – Sep 30) ☐ Quarter 4 (Oct 1 – Dec 31)
Project title: Permeability Performance and Lateral Load for Granular Backfill behind Abutments		
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WisDOT project ID: 0092-14-03	Other project ID:	Project start date: 8/13/2013
Original end date: 2/12/2015	Current end date: 2/12/2015	Number of extensions: 0

Project schedule status:
☒ On schedule ☐ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Project budget status:

Total Project Budget	Expenditures Current Quarter	Total Expenditures	% Funds Expended	% Work Completed
$150,000.00	$16,995.02	$57,909.54	39%	45%

Project description:
The current WisDOT Bridge Manual recommends using "pervious" granular backfill behind bridge abutments to prevent lateral water pressures on the abutment walls. The granular backfill material is considered "pervious" or "free-draining" based on its grain-size distribution properties. However, the "free-draining" assumption of granular backfill does not properly consider:

a) granular backfill material properties in terms of its water infiltration capacity, permeability, and water retention characteristics,
b) effect of undrained water on the lateral earth pressures exerted on the abutment walls, and
c) short- and long-term effectiveness of the pipe underdrain.

The specific research objectives of this work are to:

- Identify the current state of the practice of other state DOTs and scholarly articles addressing the influence of granular backfill permeability and water retention characteristics on the lateral earth pressure distribution and short- and long-term effectiveness of the pipe underdrain system, and collect relevant data for use in this research project.
- Conduct a thorough field investigation at 4 sites with structural backfill and granular grade 1 materials as selected by the project Technical Oversight Committee (TOC) to: (a) measure in situ permeability and water retention characteristics of the backfill materials, (b) measure in situ shear strength characteristics of the backfill materials, (c) monitor lateral earth pressures and pore pressures behind abutment walls, and (d) evaluate the performance of the pipe underdrain systems both in short- and long-term.

- Conduct a thorough laboratory investigation of the materials collected from the field sites and the alternative materials including recycled asphalt pavement (RAP) and foundry sand, to determine their shear strength, water retention, and permeability characteristics.
- Develop a practical quantitative approach to analyze lateral earth pressures on abutment walls accounting for water infiltration rate, pore pressure distribution due to infiltrated water flow, performance of pipe under drain, total unit weight, and shear strength characteristics of the backfill material.
- Develop recommendations specific to the current state of the practice of WisDOT's abutment granular backfill design and construction practices, and the impact of using alternative materials (RAP and foundry sand).

The project has been divided into the following five phases: (I) Literature Review, (II) Field and Laboratory Investigations, (III) Analysis and Evaluation of Field and Laboratory Testing, (IV) Evaluation of Alternative Materials, and (V) Final Report.

Progress this quarter (includes meetings, work plan status, contract status, significant progress, etc.):

Progress has been made this quarter on Phases I, II, and III.

<u>Phase I – Literature Review:</u>

Design and construction specifications for bridge abutment granular backfill have been collected from 31 state DOTs in the U.S. In addition, design manuals from 6 Canadian provinces have been collected and are currently being reviewed. The design manuals and specifications are reviewed for lift thickness and compaction targets, compaction methods, pipe underdrain system designs, design friction angle requirements, and drainage design and testing requirements. A summary of backfill material gradation requirements from 31 state DOTs is provided in Table 1, and lift thickness and compaction requirements are provided in Table 2. Following are key findings from preliminary review of the 31 state DOT specifications/design manuals:

- The fines content (passing the #200 sieve) specification varies between 0 to 20%. Out of the 31 state DOTs reviewed, 7 limit fines content to within 5%, 19 limit fines content to within 10%, and 29 limit fines content to within 15%.
- Most of the specifications limit lift thickness to ≤ 12 in. (range between 4 in. and 12 in.), but none of the states require QC or QA during compaction.
- All specifications require some target compaction level (95 to 100% of standard or modified Proctor maximum dry unit weight), but none of the states require QC or QA to verify compaction requirements.
- All states assume that the backfill is free-draining but is not verified with field testing, primarily because of lack of rapid testing procedures or equipment.
- Missouri, Montana and Vermont DOTs specify a design soil friction angle for backfill materials for lateral earth pressure calculations.

Literature collection in the areas specified in the proposal continued. These areas include (a) abutment granular backfill drainage design and construction procedures, (b) permeability of granular backfill materials, (c) effects of water retention (pore pressures) in backfills on lateral earth pressures, and (d) alternative materials and procedures to improve drainage and reduce lateral earth pressures.

Very limited projects that are similar to this research project exist in the literature. The research team recently met with the lead PI of a project recently conducted in Vermont, which involved collecting field pore pressure measurements in backfill materials and conducting laboratory testing on backfill materials. The research team acquired preliminary results from this study and are awaiting to review their final report which is scheduled to be published in the next few weeks.

<u>Phase II – Field and Laboratory Testing:</u> As indicated in the last QPR, a bridge abutment backfill project on SH70 near Boyceville, WI, was instrumented by the research team during the last quarter with earth pressure cells and pore pressure transducers. The data is being continuously monitored using an on-site Campbell Scientific data logger system. The data logger system experienced issues with failure in one of its components due to the extreme cold weather (-45^{o}F) temperatures during early January. Some data loss occurred during the time. The research team replaced the failed component and has visited the site 2 more times since the installation to check the data logger and download the data. The field data is currently being analyzed. In addition to instrumentation, field testing was conducted on the backfill materials

to measure permeability using air permeability test (APT) and core hole permeability (CHP) tests, and strength characteristics using dynamic cone penetrometer (DCP). Results are described below as part of the Phase III effort.

The instrumentation required for the next three bridges are being acquired. In addition to earth pressure cells and pore pressure sensors, the research team is planning to include tiltmeters on the abutments to monitor movements in the next three bridges. Preliminary data from the SH70 bridge indicated changes in earth pressures with changes in temperature, which is likely linked to the movements in the bridge abutment. Additional information from tilt meters should help explain the changes observed in the in ground stresses behind the abutment.

Phase III: Analysis and Evaluation of Field and Laboratory Investigations: Grain size analysis and standard Proctor tests were conducted on the granular backfill used on the SH70 bridge. The material is classified as a poorly graded sand (SP) and the gradation properties were within the specified limits per WisDOT specifications (Figure 1). Standard Proctor results showed an optimum moisture content of 7% with a maximum dry density of 110 pcf (Figure 2). Moisture content measurements obtained from the field were at about -4% to -2% of the optimum moisture content. The bulking moisture content of the material was at about 2%. Additional laboratory testing to measure saturated hydraulic conductivity using ISU horizontal permeameter and drained shear strength properties using direct shear testing are being performed.

A brief summary of the saturated hydraulic conductivity (k) measured from APT and CHP test results are provided in Table 3. Results obtained from CHP tests were about one order of magnitude lower than the results from APT results. Laboratory tests are being conducted on the materials obtained from the site to verify the field test results. Results from DCP test locations are shown in Figure 3 and the results showing profiles of California bearing ratio (CBR) and cumulative blows are shown in Figure 4. DCP tests were conducted in the backfill material at 1 ft, 2 ft, 3.5 ft, and 5 ft away from the abutment (along the centerline) and about 10 ft away from the abutment in the existing subgrade. Results in the backfill material showed increasing CBR with depth up to about 4 ft below surface due to the confinement effect, but showed lower CBR values below about 4 ft to the natural subgrade layer.

Anticipated work next quarter:

The following activities are anticipated during the next quarter:

1. Continue literature review process.
2. Contact Wisconsin DOT for potential projects and schedule.
3. Continue laboratory testing and analyze field instrumentation results from the first project.
4. Perform laboratory bridge abutment model tests using material obtained from bridge 1 to assess infiltration properties for numerical analysis.

Circumstances affecting project or budget:

None.

Attach / insert Gantt chart and other project documentation

	MONTH																	
	Aug-13	Sep-13	Oct-13	Nov-13	Dec-13	Jan-14	Feb-14	Mar-14	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14	Jan-15
Phase I																		
Phase II																		
Phase III																		
Phase IV																		
Phase V																		
TOC Review, Revision, and Final Submission																		

FOR WISDOT USE ONLY

Staff receiving QPR:	Date received:
Staff approving QPR:	Date approved:

Table 1. Gradation specifications from different state DOTs for bridge abutment granular backfill

State	4"	3"	2"	1.5"	1"	0.75"	0.5"	.375"	# 4	# 8	# 10	#16	# 30	# 40	#50	# 100	# 200
AZ	—	100	—	—	—	60-100	—	—	—	35-80	—	—	—	—	—	—	0-12
CA	—	100	100	—	—	—	—	—	—	—	—	—	—	—	0-100	0-8	0-4
CO	—	—	100	—	—	—	—	—	30-100	—	—	—	—	—	10-60	—	5-20
ID	—	—	—	—	—	—	—	—	30-100	—	—	—	—	—	—	—	0-5
IL	—	—	—	—	—	—	—	—	50-100	—	—	—	—	—	—	—	0-4
IN	—	—	90-100	—	—	—	—	—	20-70	—	—	—	—	—	—	—	0-8
IA	—	100	—	—	—	—	—	—	—	20-100	—	—	—	—	—	—	0-10
KS	100	—	—	—	—	—	—	—	50-100	—	—	—	—	—	—	—	0-4
KY	100	—	—	—	—	—	—	—	0-30	—	—	—	—	—	—	—	0-5
LA	—	—	—	—	—	—	100	—	—	—	—	—	—	—	—	—	0-10
ME	—	100	—	—	—	—	—	—	—	—	—	—	—	0-70	—	—	0-20
MA	—	—	—	—	—	—	50-85	—	40-75	—	—	—	—	—	8-28	—	0-10
MI	—	100	—	—	60-100	—	—	—	—	—	—	—	—	50-100	—	0-30	0-7
MN	—	—	—	—	0-100	—	—	—	—	—	—	—	—	—	—	—	0-12
MO	100	—	—	—	—	—	—	—	—	—	—	—	—	0-60	—	—	0-10
MT	—	—	100	—	—	—	—	—	20-40	—	—	—	—	—	—	—	0-8
NE	—	—	—	—	100	—	90-98	—	0-40	—	0-20	—	—	—	0-10	—	0-6
NV	—	100	—	—	—	—	—	—	35-100	—	—	—	20-100	—	—	—	0-12
NH	—	100	—	—	—	—	—	—	70-100	—	—	—	—	—	—	—	0-12
NY	100	—	—	—	—	—	—	—	0-70	—	—	—	—	—	—	—	0-15
OH	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0-20
OK	—	100	—	—	90-100	—	—	—	—	—	—	—	—	0-45	—	—	0-10
RI	—	100	—	—	—	—	—	—	30-100	—	—	—	—	—	—	—	0-8
SC	—	—	100	—	—	—	—	—	30-50	—	—	—	—	—	—	—	0-12
SD	—	—	—	—	—	—	—	100	95-100	—	—	45-85	—	—	10-30	—	0-2
TN	—	—	—	100	—	—	—	—	35-55	—	—	—	—	—	—	—	4-15
VT	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0-6
VA	—	100	95-100	—	—	—	—	—	—	—	25-55	—	—	16-30	—	—	4-14
WA	—	—	75-100	—	—	—	—	—	22-66	—	—	—	—	—	—	—	0-5
WV	100	—	—	—	—	—	—	—	—	—	—	—	—	0-60	—	—	0-15
WI	—	100	—	—	—	—	—	—	25-100	—	—	—	—	—	—	—	0-15
WY	—	—	100	—	—	—	—	—	0-50	—	—	—	0-35	—	—	0-10	0-4

Table 2. Lift thickness and compaction requirements by different state DOTs for bridge abutment granular backfill materials

State	Lift Thickness	Target Compaction Percentage	Reference Laboratory Test
AZ	8"	95	AASHTO T 99
CA	9"	95	California Test 216
CO	6"	95	AASHTO T 180
ID	8"	95	AASHTO T 99
IL	8"	95	AASHTO T 99
IN	6"	95	AASHTO T 99
IA	8"	95	AASHTO T 99
KS	8"	Specified in Contract Documents	
KY	6"	95	AASHTO T 99
LA	9"	Compacted by approved methods to the satisfaction of the engineer.	
ME	8"	Each layer thoroughly compacted by use of approved compactors before successive layers are placed.	
MA	—	—	—
MI	6"	100	AASHTO T 99
MN	8"	Compact backfill in accordance with 2105, “Excavation and Embankment,” to the specified density for adjacent and overlying embankment construction as shown the plans.	
MO	12"	90	AASHTO T 99
MT	8"	95	AASHTO T 99
NE	6"	100	AASHTO T 99
NV	8"	95	Nev. T101G
NH	8"	95	AASHTO T 99
NY	6"	95	AASHTO T 99
OH	8"	Compact all embankment materials, except for rock and hard shale, in horizontal lifts to a dry density greater than the percentage of maximum dry density in Table 203.07-1.	
OK	6"	95	AASHTO T 99
RI	12"	95	AASHTO T 180
SC	8"	95	SC-T-29
SD	6"	97	AASHTO T 99
TN	6"	100	AASHTO T 100
VA	6"	95	VTM-12
WA	6"	95	AASHTO T 99/AASHTO T 180
WV	4"	95	AASHTO T 99
WI	8"	Compact each layer, before placing the next layer, by using engineer approved rollers or portable mechanical or pneumatic tampers or vibrators.	
WY	8"	Compact it to the same density as adjacent material.	

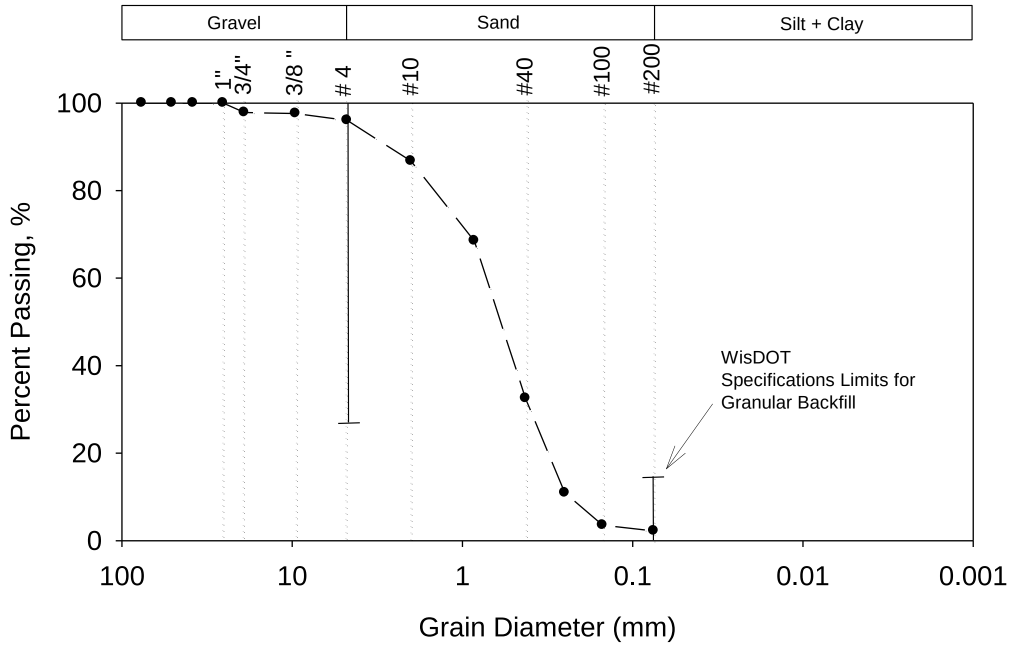

Figure 1. Gradation results for granular backfill used on SH70 project

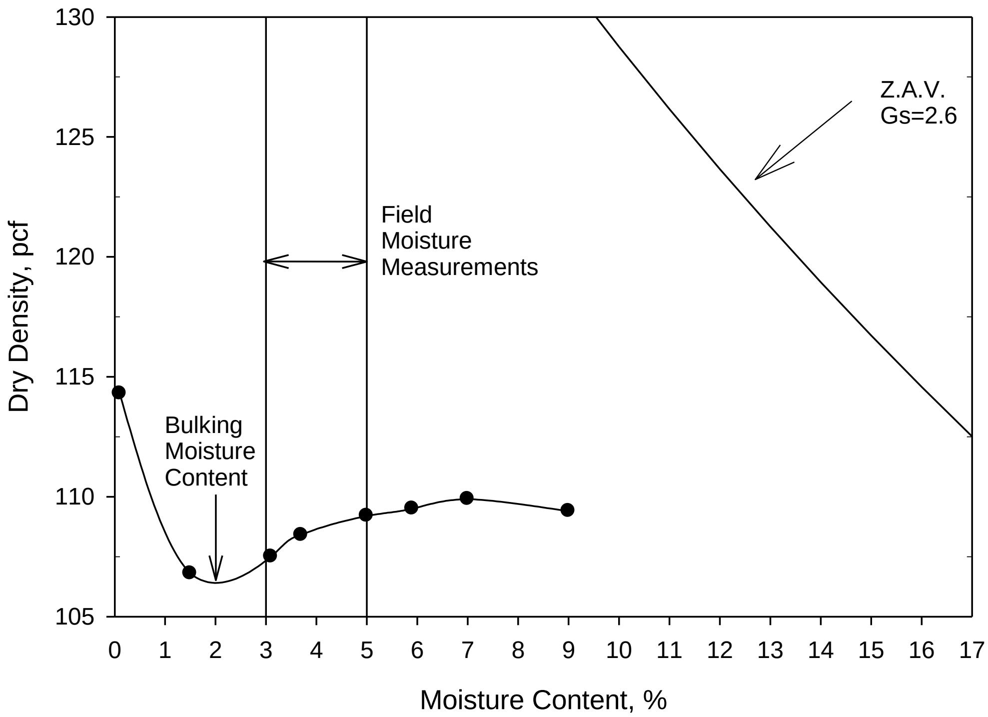

Figure 2. Standard Proctor results for granular backfill used on SH70 project

Table 3. Saturated hydraulic conductivity results from APT and CHP tests

Test Location	APT (cm/s)	CHP (cm/s)
5.5 ft. South of Centerline of Abutment	0.84	0.099
Center of Abutment	0.84	0.099
5.5 ft. North of Centerline of Abutment	0.84	0.103

Figure 3. Location for DCP testing on SH 70 bridge abutment

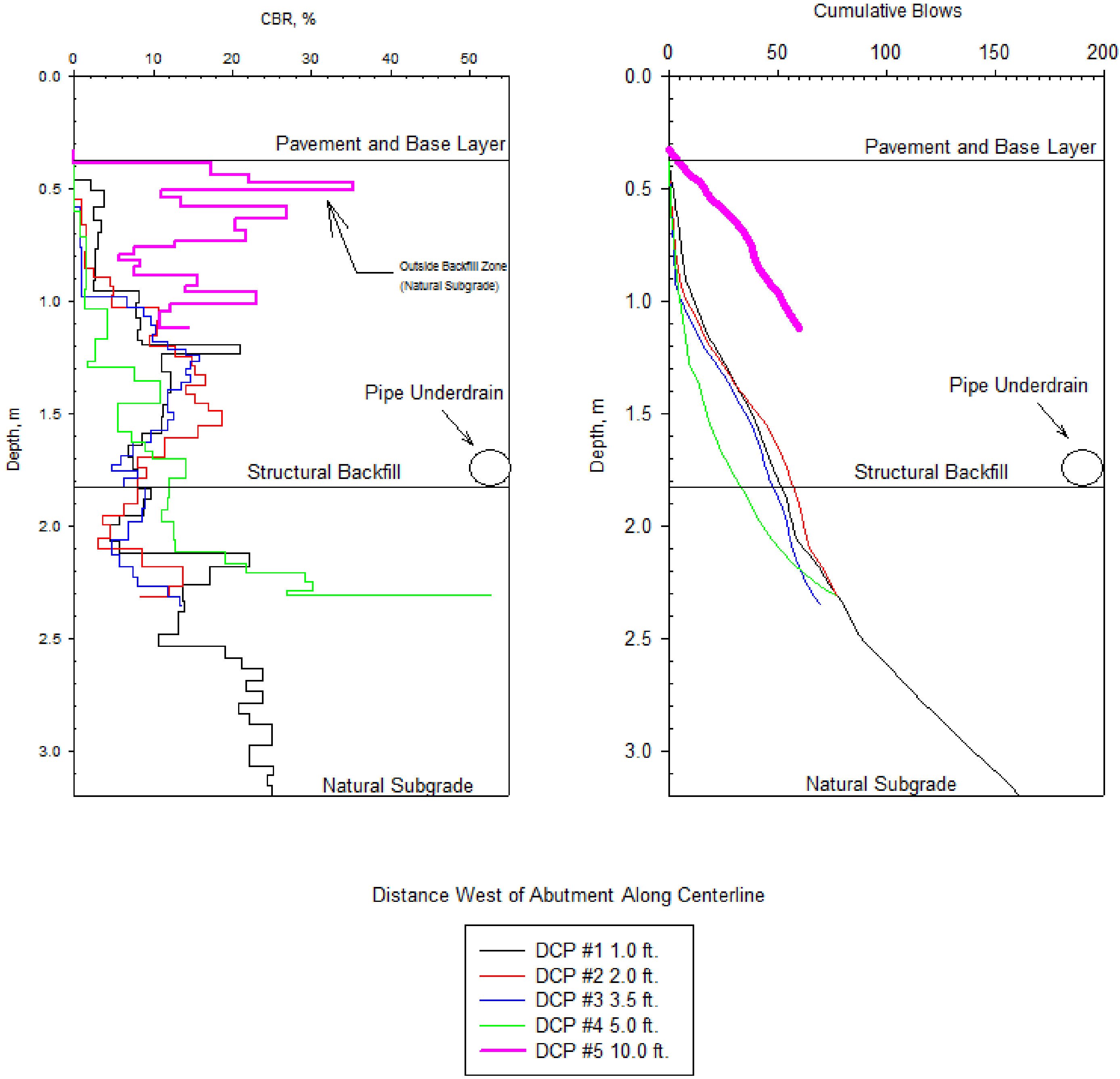

Figure 4. DCP test results from SH 70 Bridge